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NUCLEAR MAGNETIC RESONANCE SPECTRA OF DERIVATIVES OF VARIOUS SUBSTITUTED INDANONES AND TETRALONES

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Abstract—The proton NMR spectra of a series of 2-benzal-, 2-benzyl-, and 2-benzyl-2-bromo-indanones and a series of substituted 4,4-dimethyltetralones have been determined. The *cis* and *trans* isomers of 2-benzalindanones are easily identified through analysis of their PMR spectra. Peculiarities in the complex spectra of 2-benzyl and 2-benzyl-2-bromoindanones and tetralones are partially accounted for on the basis of conformational preference about the carbon–carbon bond attaching the 2-benzyl moiety to the 2-position of the indanone and tetralone rings. An internal complexation between the benzyl phenyl and the carbonyl group may be involved in some of these structures. The 4,4-dimethyltetralones exhibited two methyl resonances as a result of substitution in the 2-position and the stereo-structures are discussed in terms of conformational analysis.

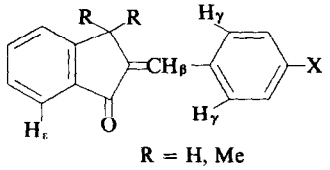
INTRODUCTION

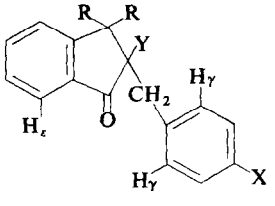
THIS NMR spectroscopic study was made in connection with the investigation of elimination reactions of α-halogenated ketones[3] being carried on in this laboratory. Considerations concerning the topology of bimolecular dehydrobromination transition states seemed to require an understanding of the configuration and of the preferred conformation of the 2-halogeno-2-benzylindanones and tetralones. This has been attempted using the NMR data of these compounds.

Furthermore, as these 2-benzylindanones were obtained by hydrogenation of the corresponding 2-benzalindanones and as the *cis-trans* isomerism of these compounds is of considerable interest in this laboratory,[4] a complete NMR spectroscopic study of this isomerism was also undertaken.

RESULTS AND DISCUSSION

The pertinent protons of a series of substituted 2-benzal and 2-benzylindanones have been classified as shown:





R = H, Me
X = H, Me, OMe, Cl, OMe_2, NO_2
Y = H, D, Br

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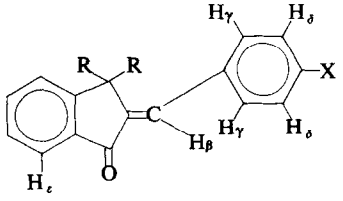
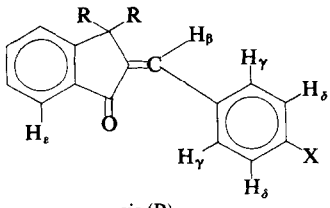
[3] D. N. Kevill, E. D. Weiler and N. H. Cromwell, *J. Am. Chem. Soc.* **88**, 4489 (1966) and Refs therein.

[4] D. N. Kevill, E. D. Weiler and N. H. Cromwell, *J. Org. Chem.* **29**, 1276 (1964), and Refs therein.

TABLE 1. NMR SPECTRA OF DERIVATIVES OF 2-BENZAL-1-INDANONE



trans (A)



cis (B)

Compound[a]				Chemical Shifts (δ, ppm) (J, c/s)					
	Ref.	R	X	R	H_β	A_2B_2 pattern (except when X = H)	H_ε[i]	other aromatic protons	X protons
1A	4	H	H	3·95[c](2)			7·82	7·25–7·65	
1B	4	H	H	3·84[c](1·5)	6·88[f](1·5)		7·82	7·30–8·25	
2A	3	H	Me	3·97[c](2)	*e* —	*e* —	7·91	7·30–7·75	2·36
2B	3	H	Me	3·87[d]	6·96[d]	8·12, 7·98; 7·30, 9·17	7·84	7·25–7·60	2·37
3A	3	H	OMe	3·94 (2)	*e* —	*j*; 7·03, 6·88	7·89	7·25–7·70	3·82
3B	3	H	OMe	3·81[k]	6·87[d,g]	8·25, 8·10; 5·99, 6·84	7·84	7·25–7·70	3·81[k]
4A	3	H	Cl	4·02[c](2)	*e* —	*e* —	7·97	7·30–7·75	
4B	3	H	Cl	3·85[d]	6·91[l](1·5)	8·12, 7·98; *j*	7·86	7·20–7·65	
5A	6	H	NMe_2	3·87[c](2)	*e* —	*j*; 6·72, 6·59	7·86	7·20–7·65	2·95
6A	4	CH_3	H	1·50	7·65[h]		7·79	7·20–7·60	
6B	4	CH_3	H	1·55	6·78		7·73	7·20–8·20	
7A	(b)	CH_3	OMe	1·62	*e* —	*j*; 7·10, 6·98	7·94	7·25–7·35	3·89
7B	(b)	CH_3	OMe	1·55	*g* —	8·29, 8·16; 7·05, 6·92	*e*	7·25–8·00	3·89
8A	3	CH_3	Cl	1·50	*e* —	*e* —	7·83	7·20–7·70	
8B	3	CH_3	Cl	1·57	6·78	8·14, 8·00; *j*	7·78	7·20–7·60	

[a] Solvent $CDCl_3$, except for compounds 1, 6 and 8 which were run in CCl_4;
[b] This publication.
[c] Center of a doublet.
[d] Non-resolved.
[e] Hidden by the aromatic protons.
[f] Triplet.
[g] Partly hidden by the A_2B_2 system.
[h] On deuteration of H_β this resonance disappears completely.
[i] Center of a complex multiplet.
[j] The other part of the A_2B_2 system is with the aromatic protons.
[k] The MeO group and the methylene protons are at the same field (integration 5 protons).
[l] This spectrum has been described in the Varian catalogue (Ref. 5 spectrum No. 649) in $CDCl_3$ as solvent, with the following assignments: 4·04 doublet, H-3; 7·55, H_β and 7·92 center of a doublet for H_ε. However, it seems to us difficult to admit that the peak of 7·55 corresponds to H_β, this band being on the middle of the complex aromatic multiplet. Furthermore, the NMR spectrum of the corresponding deuterated compound (in β position) shows that this band is always present; the 4·04 signal being now a singlet instead of a doublet.

For all of these compounds, the H_ε proton is part of a four spin system (unsymmetrical *ortho* disubstituted benzene). It has been observed by others that aromatic protons adjacent to a carbonyl moiety are always found at lower field than the remaining aromatic protons, and so can be easily distinguished.[5] This is, of course, a result of the anisotropic effect of the carbonyl group. For all the systems studied here (indanone and tetralone) H_ε is easily distinguished in the aromatic pattern and appears always in the range 7·82–8·07 δ (i.e. Tables 1, 2 and 4; the values given represent the center of a complex multiplet).

In Table 1 are found the NMR spectral data for a series of *cis* (B) and *trans* (A) isomeric 2-benzal-1-indanones. It is immediately apparent through examination of this Table that the pairs of isomers are easily identified by examining the relative positions of proton H_β and of the pattern corresponding to protons H_γ.

In the *trans* (A) compounds, H_β lies in the deshielding region of the carbonyl group; for this reason, H_β is shifted downfield and generally masked (except for compound 6A) by the complex multiplet arising from the remainder of the aromatic protons. In the *cis* (B) compounds, H_β appears as a singlet (when R = Me) or as a triplet, or a non-resolved triplet (when R = H) in the 6·78–6·96 region. This splitting, for compounds **1** to **5**, is due to allylic coupling with the two hydrogens in the 3-position. These two protons appear generally as a doublet and it can be seen from Table 1 that, for a pair of isomers, J *trans* > J *cis*. However, the difference in coupling constants is very small and cannot be used for identification purposes; further, the reverse sequence (J *cis* > J *trans*) has also been observed for the allylic coupling constant.[7, 8]

Just as for H_β, the position of the H_γ is similarly controlled by the diamagnetic anisotropy of the carbonyl group. For all the *cis* (B) compounds (except when X = H), the H_γ protons will be deshielded and the low field doublet, corresponding in first approximation to the H_γ part of the A_2B_2 system, appears at lower field than H_ε. When X = H (compounds **1** and **6**) no further A_2B_2 system exists and for the *cis* (B) isomers, a pattern, corresponding to two protons arises also at lower field than H_ε. In the *trans* (A) isomers, the doublet appears at higher field and is generally masked by the complex multiplet arising from the aromatic protons.

In Table 2 are found the NMR spectral data of some 2-benzylindanones. When R = Y = H (compounds **9**, **12**, **14**, **16**, **18**), the five methylenic protons give a complex pattern in the 2·40–3·70 δ region. For the 2-deuterio-2-(α,α-dideuteriobenzyl) compound **11**, the two protons in position 3 give an AB system with $J = /18/c/s$.[12] The same coupling constant has been reported for other 2-benzylindanones.[10]

For the 2-bromo derivatives (**10**, **13**, **15**, **17**, **19**) the signals corresponding to the benzylic CH_2 and to the methylenic protons in the 3-position are in the same range and give an AB system mixed with an A_2 or another AB system. However, by replacing the

[5] NMR Spectra catalog, Varian Associates, 1962 and 1963,—for example see spectra no. 496, 552, 621, 649 etc.

[6] G. A. Coppens, M. Coppens, D. N. Kevill and N. H. Cromwell, *J. Org. Chem.* **28**, 3267 (1963).

[7] R. R. Fraser and D. E. McGreer, *Canad. J. Chem.* **39**, 505 (1961) and Refs therein.

[8] M. Martin, G. Martin and P. Caubere, *Bull. Soc. Chim. Fr.* 3067 (1964).

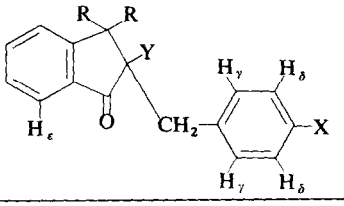
[9] N. H. Cromwell and R. P. Ayer, *J. Am. Chem. Soc.* **82**, 133 (1960).

[10] D. N. Kevill, G. A. Coppens, M. Coppens and N. H. Cromwell, *J. Org. Chem.* **29**, 382 (1964).

[11] B. P. Pearson, R. P. Ayer and N. H. Cromwell, *J. Org. Chem.* **27** 3038 (1962).

[12] The *geminal* coupling constant is now considered to be negative, e.g. J. A. Pople and A. A. Bothner, *J. Chem. Phys.* **42**, 1339 (1965).

TABLE 2. NMR SPECTRA OF DERIVATIVES OF 2-BENZYLINDANONE



Compound[a]					Chemical Shifts (δ, ppm) (J, c/s)			
No.	Ref	R	Y	X	Methylenic protons	H_ϵ[e]	Aromatic protons	X
9	9	H	H	H	Complex pattern, 2·40–3·58	7·78	7·10–7·65	
10	9	H	Br	H	AB system: 3·50, 3·41 J = /14/c/s Singlet (2 protons) 3·49	7·77	7·10–7·58	
11	10	H	D	H	AB system: 3·02, 2·76[h,b] J = /18/	7·63	7·00–7·80	
12	3	H	H	CH_3	Complex pattern 2·50–3·40	7·75	7·00–7·60[e]	2·27
13	3	H	Br	CH_3	3·48–3·70[b]	7·86	7·10–7·60[e]	2·26
14	3	H	H	OCH_3	Complex pattern 2·50–3·50	7·81	6·80–7·60[e]	3·78
15	3	H	Br	OCH_3	3·25–3·75[b] with half of an AB system J = /14/	7·86	6·70–7·75 with A_2B_2 system: 6·74, 6·88, 7·16, 7·30	3·73
16	3	H	H	NO_2	Complex pattern 2·60–3·70	7·80	7·20–7·65 A_2B_2 system —; 8·13, 8·25	
17	3	H	Br	NO_2	3·45–3·75[b]	7·85	7·20–7·70 A_2B_2 system —; 8·12, 8·25	
18	3	H	H	Cl	Complex pattern 2·60–3·50	7·81	7·20–7·65[e]	
19	3	H	Br	Cl	3·10–3·85[b]	7·77	6·85–7·60[e]	
					R			
20	11	CH_3	H	H	1·18	ABC system 2·45–3·60	7·65	7·10–7·55
21	11	CH_3	Br	H	1·35, 1·41	AB system: 3·21, 3·59[i] J = /15/	7·77	7·10–7·60
22	3	CH_3	H	Cl	1·22, 1·30	ABC system 2·40–3·45		7·15–7·90[e]
23	3	CH_3	Br	Cl	1·44	AB system: 3·12, 3·46 J = /15/	7·82	7·15–7·70[e]
24	g	CH_3	H	OCH_3	1·17, 1·19	ABC system 2·35–3·45	7·60	7·0–7·50 A_2B_2 system 6·65, 6·78, 7·07, 7·23	3·76
25	g	CH_3	D	H	1·20	AB system: 3·46, 2·62 J = /15/	7·65	7·10–7·55	

[a] Solvent CCl_4.

[b] The integration is four protons—in some spectra part of an AB system is detected.

[c] Center of a complex multiplet.

[d] The other part of the A_2B_2 system is hidden by the aromatic protons.

[e] The A_2B_2 system is completely hidden by the aromatic protons.

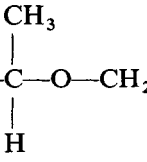
[f] Hidden by the aromatic protons.

[g] This publication.

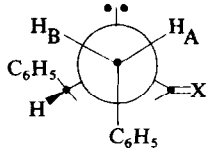
[h] This compound is 2-deuterio-2-[α,α-dideuteriobenzyl] 1-indanone.

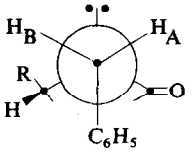
[i] In CH_3CN as solvent, the methylenic protons give only one peak at 3·34 δ; the two methyl groups are at 1·37 and 1·47 δ.

hydrogen atoms in the 3 position by two methyl groups (**21**, **23**, **25**), an AB system, (with J = /15/ c/s) corresponding, of course, to the two benzylic hydrogens, is detected. Because of the dissymmetry at the 2-carbon atom, these benzylic protons are stereochemically non-equivalent and are designated as diastereomeric.[13]

The origin of the non-equivalence of such protons has been extensively studied,[14–18] and as Roberts points out,[15] the conformational preference with respect to the asymmetric center must be, in general, responsible for the major contribution to the magnetic non-equivalence. For example to explain the non-equivalence of the benzyl protons in a benzyl ether of structure  , Roberts[14] suggests that the proximity of the asymmetric center to the benzyl group results in a preferred conformation of the phenyl ring with respect to the methylene protons and that the principal contribution to the non-equivalence originates in the magnetic anisotropy of the phenyl group.

Other examples of such diastereomeric protons in benzyl systems were also recently reported by Southwick, *et. al.*[19] and by Lewin, *et al.*[20] for the 1-benzyl-2-imidazolidinone I (or -2-imidazolidinethione II) system and for 2-benzylphthalimide system III and IV, respectively. The large differences in chemical shifts between the two benzylic protons were explained on the basis of preferred conformations such as those represented below.





I: X = O $\delta H_A - \delta H_B = 1{\cdot}30$ III: R = C_6H_5 $\delta H_A - \delta H_B = 1{\cdot}75$
II: X = S $\delta H_A - \delta H_B = 1{\cdot}85$ IV: R = CH_3 $\delta H_A - \delta H_B = 0{\cdot}70$
Solvent CCl_4, J_{AB} = 15 c/s. Ref. 19 and 20

FIG. 1.

The proton H_A is deshielded by the carbonyl group (or thio-carbonyl group for II); H_B is shielded by the Ph group (except for IV). Generally speaking, the non-equivalence

[13] K. Mislow, M. A. W. Glass, H. B. Hopps, E. Simon and G. H. Wahl, Jr., *J. Am. Chem. Soc.* **86**, 1710 (1964).

[14] G. M. Whitesides, J. J. Grocki, D. Holtz, H. Steinberg and J. D. Roberts, *J. Am. Chem. Soc.* **87**, 1058 (1965) and Ref. therein.

[15] G. M. Whitesides, D. Holtz and J. D. Roberts, *J. Am. Chem. Soc.* **86**, 2628 (1964).

[16] J. C. Randall, J. J. McLeskey, P. Smith and M. E. Hobbs, *J. Am. Chem. Soc.* **86**, 3229 (1964).

[17] W. L. Meyer, D. L. Davis, L. Foster, A. S. Levinson, V. L. Sawin, D. C. Shew and R. F. Weddleton, *J. Am. Chem. Soc.* **87**, 1573 (1965).

[18] M. L. Martin and G. J. Martin, *Bull, Soc. Chim. Fr*, 2117 (1966).

[19] P. L. Southwick, J. A. Fitzgerald and G. E. Milliman, *Tetrahedron Letters* No. **18**, 1247 (1965).

[20] A. Lewin, L. Lipowitz and T. Cohen, *Tetrahedron Letters* No. **18**, 1241 (1965).

of the benzylic protons is a consequence of a difference in the shielding by two diastereomeric environments; the molecule may or may not be in a preferred conformation.

If the non-equivalence of the benzylic protons in the indanones is due only to the asymmetry (i.e. there is no preferred conformation) then two signals would be expected from the two Me groups in the 3-position, the Me eclipsed to the benzyl being influenced by the diamagnetic anisotropy of the Ph group. However, for **20** and **25**, the two Me groups give only one signal, i.e. they are magnetically equivalent. An explanation for this is that the phenyl ring is rotated away from the eclipsed Me group (see conformation A). For all the other possible conformations, and in particular for conformations such as B, the two Me groups should not be equivalent.

Conformation A Conformation B

FIG. 2.

A possible explanation for a preferred conformation is as follows: it has been shown that a benzene solvent molecule forms a stereospecific 1:1 collision complex with a ketone group.[21-24] It was previously suggested[25-27] that in this complex, the π-electron system of the benzene ring and the positive charge of the C=O dipole interact in approximately a planar association.[27d]

However, more recent data,[21, 27d] on the 11-oxo-5α steroids show that the solvent benzene ring must be almost at right angles to the overall plane of the steroid molecule, and with the benzene molecule oriented as far as possible from the negative end of the C=O dipole. Thus, it can be assumed that the formation of such a lowest energy complex, whatever the exact orientation of the Ph ring is, accounts for the existence of a preferred conformation in which the Ph group of the 2-benzylindanone molecule forms an *internal* complex with the keto group.

If such an internal complex is formed, elevation of the temperature or changing to a more polar solvent can be expected to give more freedom to the benzyl group so that the Me groups become non-equivalent. It can be seen from Table 3 that at 75° the two Me groups of **20** are distinct (for 3,3-dimethylindanone, only one Me signal is of course detected on varying the temp). By introduction of a bromine atom in the 2-position (**21**) the two Me groups are differently deshielded and are no longer

[21] D. H. Williams and D. A. Wilson, *J. Chem. Soc.* (B) 144 (1966) and Ref. therein.
[22] S. Bory, M. Fetizon, P. Laszlo and D. H. Williams, *Bull. Soc. Chim. Fr*, 2541 (1965).
[23] P. Laszlo and D. H. Williams, *J. Am. Chem. Soc.* **88**, 2799 (1966).
[24] D. H. Williams and N. S. Bhacca, *Tetrahedron Letters* **21**, 2021 (1965).
[25] N. S. Bhacca and D. H. Williams, *Tetrahedron Letters* 3127 (1964).
[26] J. V. Hatton and R. E. Richards, *Mol. Phys.* **5**, 153 (1962).
[27] N. S. Bhacca and D. H. Williams, *Application of NMR Spectroscopy in Organic Chemistry*. Holden-Day, San Francisco (1964). [a] p. 19, 31; [b] p. 51; [c] chapter 7; [d] J. Ronayne and D. H. Williams, *Chem. Comm.* 712 (1966).

TABLE 3. NMR METHYL SIGNALS (δ, PPM) AT 25° AND 75° (CCl_4 AS SOLVENT)

Compound	25°	75°
2-Benzyl-3,3-dimethylindanone (**20**)	1·18	1·17
		1·20
2-Bromo-2-(p-chlorobenzyl)-		
3,3-Dimethylindanone (**23**)	1·44	1·46
		1·50

7

equivalent, but since the benzylic protons present an AB system the compound can also be considered to exist in a preferred conformation. As expected in MeCN as solvent, the benzylic protons give only one peak. However, the introduction of a chlorine atom, or of a OMe group, in the *para* position to the CH_2 groups (compounds **22** to **24**) led to different results. With an hydrogen atom in the 2-position (**22** and **24**), the two Me groups are non-equivalent, but by introduction of a bromine atom in the 2-position (compound **23**), there is only one Me signal.

We can consider that the introduction of a polar *para* substituent destroys the complex between the C=O and the Ph group and consequently changes the preferred conformation. But as the two benzylic protons show an AB system (**23**), there is likely to be a preferred conformation in which the CH_2—C_6H_4—Cl dipole is opposed to the C=O dipole (or to the resultant of the C=O, C-Br dipoles). For compound **22** a preferred conformation in which the Me group eclipsed to the benzyl is in the deshielding region of the benzene ring apparently exists. By the introduction of a bromine atom in the 2-position (**23**) the deshielding of the two Me groups (one eclipsed to the bromine atom, the other one to the benzyl group) is accidentally equivalent and, at 75°, these two Me groups are no longer equivalent (Table 3), the benzyl group being more free to rotate.

The different conformations of 2-benzyl and 2-*p*-substituted benzylindanones can be related to the different rates of elimination reactions of **21** and **23** with halide ions[3] which imply that the topology of the transition state of bimolecular dehydrobromination is different for these two compounds.

The stereochemistry of the tetralones presented in Table 4 has been determined previously using IR and UV data.[28] The NMR spectra of these compounds wi v be considered in terms of conformational analysis to confirm their stereostructure.

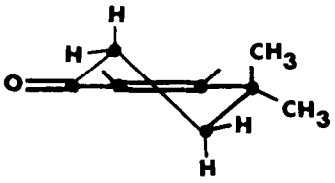
4,4-Dimethyl-1-tetralone is not a planar molecule and it should exist in staggered quasi-chair conformations.[28] The carbonyl group was first considered to form an angle of 22°[29] with the plane of the unsaturated system;[30] however, more recent work by Huisgen[31] shows this angle to be near zero. At room temperature, 4,4-dimethyl-1-tetralone (**26**) exists in two conformations, C and D, and these two

[28] A. Hassner and N. H. Cromwell, *J. Am. Chem. Soc.* **80**, 893 (1958).

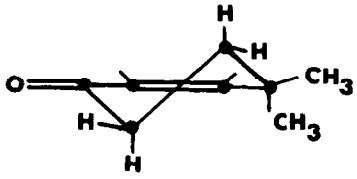
[29] E. A. Braude and F. Sondheimer, *J. Chem. Soc.* 3754 (1955).

[30] This value was calculated by comparing the intensities of UV absorption of 1-tetralone and acetophenone; using the same method, this angle was found to be 17° for the indanone. This value is also obviously erroneous as Huisgen[31] points out. Furthermore, the NMR spectrum of 3,3-dimethylindanone shows only one Me peak (1·40 δ, $CDCl_3$ as solvent), and as this molecule is not flipping, one would expect on the basis of an angle of 17° the methyls to be magnetically different. This molecule should be also nearly planar.

[31] R. Huisgen, G. Seidl and I. Wimmer, *Liebigs Ann.* **677**, 21 (1964).



C



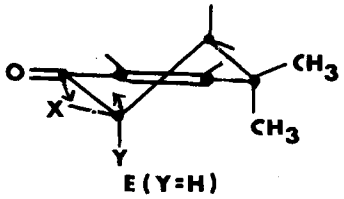
D

conformers are interconverted sufficiently rapidly to average out the difference in chemical shift expected for pseudo-axial and pseudo-equatorial Me groups. The NMR spectrum of **26** (Table 4) shows only one Me signal and a symmetrical A_2B_2 system corresponding to the four methylenic protons.

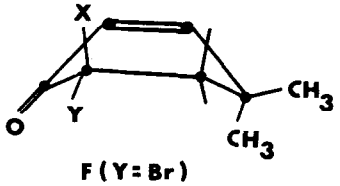
The introduction of a substituent in the 2-position should increase the difference of energy between the two conformers and could cause one form to predominate. For **27** to **29**, one expects, respectively, the bromine atom and the benzyl group to take up preferentially the pseudo-equatorial position in order to minimize the steric interactions with the axial Me group.[28] Hence, the difference between the pseudo-axial and pseudo-equatorial Me groups is no longer averaged out and the NMR spectra of these compounds (Table 4) show two Me signals. This is also the case for the other 2,2-disubstituted tetralones described here (**30**, **31**).

In steroids, the axial C_{19} Me resonance is much more influenced by an axial halogen atom than by an equatorial one: for a 2α Br atom, the shift on the C_{19} Me group is 0·075 ppm, but 0·23 ppm for a 2β Br atom.[25]

However, as the stereostructures of these two series of compounds are different, the analogy with the steroids must be used very carefully. Further, the introduction of one substituent in the 2-position may produce a variation of the geometry of the ring and if it can be assumed that for a pseudo-equatorial substituent in the 2-position the ketone ring is in a staggered quasi-chair conformation (as E), the introduction of a second substituent in the 2-position can force the ring to be nearer to a boat form (F), each intermediate conformation being of course possible.



E (Y=H)



F (Y=Br)

Such a boat conformation was assumed by Johnson,[32] *et al.* to explain the low reactivity of 4,5-dimethyltetralone with Grignard reagent.

Compared to **26**, the deshielding of the two Me peaks of **27** is 0·05 and 0·11 ppm. The more deshielded Me peak probably corresponds to the pseudo-axial Me group (δ, 1·48 ppm) and as the observed deshielding (0·11 ppm) is closer to the deshielding produced by an equatorial bromine atom in steroids, the bromine atom in **27** is thus pseudo-equatorial.

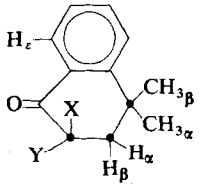
[32] G. D. Johnson, S. Searles Jr. and Wen-chung Lin, *J. Org. Chem.* **27** 4031 (1962).

The chemical shifts of hydrogen atoms attached to a carbon atom bearing a halogen in a large number of α-haloketones have been reported to occur in the δ, 4·0–5·1 region.[33] The three methylenic protons of **27** are expected to give an ABX system, and the low field quartet (integration one proton, 4·79–5·10 δ) is of course the X part of this system and corresponds to the proton in the 2-position on the same carbon as the bromine atom. However, at higher field only two peaks (integration one proton each) are detected, one of them being slightly split. In a first order treatment, the splitting of this low field quartet (9–10 c/s) is in favor of a *trans* diaxial coupling[27b] and thus the bromine atom is pseudo-equatorial.

Using IR and UV data,[28] the 2-benzyl derivatives **28** and **31** were assumed to have the benzyl group in the pseudo-equatorial position and the other substituent (D, H, Cl, Br) in a pseudo-axial position. But the conformation of the ring could change from compounds **28** and **29** to compounds **30** and **31** because of the introduction of a second substituent in the 2-position. However, it can be seen from Table 4 that of the two Me signals, one is relatively constant (1·21–1·25 ppm) and this Me is presumably pseudo-equatorial.

The position of the other Me signal depends on the axial substituent in the 2-position. Just as for the C_{19} Me resonance in steroids,[27a] the Me signal is shifted downfield by 0·26 ppm when X = Br (comparison of **28** and **31**), which is in agreement with an axial halogen atom; when X = Cl, the shift is only 0·18 ppm (comparison of **28** and **30**), but this is consistent with a pseudo-axial chlorine atom (for the C_{19} Me resonance, in steroids, the deshielding introduced by an equatorial chlorine atom is only 0·08 ppm[27a]).

TABLE 4. NMR SPECTRA OF SOME TETRALONES



Compounds			Chemical Shifts (δ, ppm) (J, c/s)			
	X	Y	α	$^{Me}\beta$	Methylenic protons	H_ε[b]
26	H	H	1·37		A_2B_2 symetrical pattern between 1·83–2·75	7·92
27	H	Br	1·42	1·48	Quartet: 5·10; 4·95; 4·94; 4·79	7·97
					Doublet: 2·58 (1) singlet 2·44	
28	H	$CH_2Ø$	1·22	1·31	Complex five spin pattern between 1·60–3·70	7·97
29	D	$CH_2Ø$	1·21	1·30	Benzylic protons: 2·57, 3·43, J_{AB} = /14/ H_α[a] or H_β = 1·72	7·94
30	Cl	$CH_2Ø$	1·25	1·49	Benzylic protons: 3·41 H_α = H_β = 2·21	8·02
31	Br	$CH_2Ø$	1·23	1·57	Benzylic protons: 3·47, 3·68, J_{AB} = /14/ H_α = H_β = 2·29	8·07

[a] One of the two methylenic protons is replaced by a deuterium.
[b] Center of a complex multiplet.

[33] A. Nickon, M. A. Castle, R. Harada, C. E. Berkoff and R. O. Williams, *J. Am. Chem. Soc.* **85**, 2185 (1963).

As in the 2-benzylindanone series, the geminal benzylic protons of the 2-benzyltetralones are non-equivalent and show an AB system (compounds **29**, **31**); however, for the 2-chloro compound (X = Cl, **30**) only one signal is detected.[34]

For these compounds the benzyl group is in a pseudo-equatorial position, and it would have been quite difficult to consider a planar complex between the ketone group and the phenyl ring. But as Williams[21] showed recently that the solvent benzene ring is almost at right angles to the plane of the ketone group in intermolecular complexes, a preferred conformation in which the Ph group, roughly perpendicular to the overall plane of the molecule, forms a complex with the ketone group, can be assumed.

The diastereomeric protons in the 3-position of the tetralone ring give only a single peak, i.e. they are magnetically equivalent.

Two conditions for this equivalence are conceivable:

(a) a rapid conformational interchange of the diastereomeric environment; however, the NMR spectra of the 2-benzyltetralones show that these molecules are not flipping; and/or (b) a very small difference in the chemical shift of the two protons. The chemical shift difference between diastereomeric protons is known to be sensitive to a change of solvent;[13-15] however, this effect is not fully understood but it should be connected with a change in the preferred conformation. When one of the substituents on the asymmetric center is an unsaturated group, Roberts showed that the chemical shift difference between the two benzylic protons decreases with an increase of the dielectric constant of the solvent.[14]

TABLE 5. SOLVENT EFFECT ON THE METHYLENIC PROTONS OF 2-CHLORO-2-BENZYL-4,4-DIMETHYL-1-TETRALONE (**30**) AND 2-BROMO-2-BENZYL-4,4-DIMETHYL-1-TETRALONE (**31**). NMR STUDIES.

	Compound **30**		Compound **31**	
Solvent	$CH_2 - Ø$	ring CH_2	$CH_2 - Ø$	ring CH_2
C_6H_{12}	3·34, 3·51 J = /14/ c/s	2·20	3·45, 3·76 J = /14/cps.	2·30
CCl_4	3·41	2·21	3·47, 3·68 J = /14/ c/s	2·29
$CHCl_3$	3·46	2·23, 2·34 J = /16/c/s	3·53	2·34
CH_3CN	3·44	2·26, 2·46 J = /16/ c/s	3·58	2·34, 2·49 J = /16/ c/s

Such a behaviour is found for benzylic protons of compounds **30** and **31**. (Table 5). Since the preferred conformation of the benzyl group with respect to the ketone group is responsible for the major part of the magnetic non-equivalence of the benzylic protons, there is apparently a change in the conformation of the molecule (or in the proportion of conformers) in going from non-polar to polar solvent.

[34] This behavior is not too surprising as Roberts[15] showed that one of the factors which influence the degree of magnetic non-equivalence of benzylic protons is the size of the substituent on the asymmetric center, the magnitude of the chemical shift difference being proportional, in similar series of substituents, to the size of this substituent. Furthermore, in cyclohexane as solvent, compound **30** (X = Cl) shows an AB system for the benzylic protons.

For the two methylenic protons, the reverse effect is found (increase of chemical shift difference with increasing dielectric constant), but for these protons, the diamagnetic effect of the ketone does not interfere as free rotation around the C_2—C_3 bond is not possible.

As the conformations of these molecules are not fully fixed (there is a possibility of going from a quasi-chair form to a quasi-boat form by changing the solvent), it is impossible to decide if this solvent effect is connected with a change in the intermolecular complex and/or with a variation of the geometry of the ring.

EXPERIMENTAL[35]

trans-2-(-p-*Methoxybenzal*) 3,3-*dimethyl*-1-*indanone* (**7A**). A chilled soln of 6·56 g (0·04 mole) of 3,3-dimethyl-1-indanone in 35 ml EtOH was added to a soln containing 0·30 g (0·0054 mole) KOH in 25 ml EtOH. To this cold soln was added rapidly 5·45 g (0·04 mole) freshly distilled anisaldehyde. The yellow soln stood in the freezer for 14 days before light yellow crystals were formed. The PMR spectrum showed this to be the *trans*-isomer, 4·2 g (39% yield) m.p. 79–82°. (Found: C, 81·90; H, 6·49. Calc. for $C_{19}H_{18}O_2$: C, 81·98; H, 6·52%.)

The IR spectrum showed the following bands, $\nu_{cm^{-1}}^{CHCl_3}$: C = 0, 1690 (s); Ar, 1602 (s). The UV spectrum showed $\lambda_{m\mu}^{MeOH}$, 348 (ε, 19,450), 247 (ε, 12,180).

cis-2-(p-*Methoxybenzal*) 3,3-*dimethyl*-1-*indanone* (**7B**). The *cis*-isomer could not be obtained pure due to rapid equilibration to a mixture of *cis* and *trans* forms. The PMR spectrum of *cis*-2-(*p*-methoxybenzal) 3,3-dimethyl-1-indanone is reported in Table 2. (Found: C, 81·93; H, 6·73). Mixture of *cis* and *trans* forms, Calc for $C_{19}H_{18}O_2$: C, 81·98; H, 6·52%.)

2-(p-*Methoxybenzyl*) 3,3-*dimethyl*-1-*indanone* (**24**). A 0·60 g amount of 10% Pd-C in 50 ml dioxan was introduced into the hydrogenation bottle, pre-reduced and equilibrated with hydrogen–dioxan vapor at atm press. A 0·024 mole sample of 2-(*p*-methoxybenzal) 3,3-dimethyl-1-indanone in 250 ml dioxan was then introduced and hydrogenated at atm press until H_2 uptake ceased. The catalyst was removed by filtration, the dioxan evaporated under reduced press and the resulting light yellow oil crystallized from MeOH–water, giving a 95% yield of **24**, m.p. 74–75°. (Found: C, 80·99; H, 6·89. Calc. for $C_{19}H_{20}O_2$: C, 81·39; H, 7·19%.)

The IR spectrum showed the following bands, $\nu_{cm^{-1}}^{CCl_4}$: C = 0, 1715 (s); Ar, 1610 (m). The UV spectrum showed: $\lambda_{m\mu}^{CH_3OH}$, 286 (ε, 4,800), 281 (ε, 4,870), 245 (ε, 14,600), 229 (ε, 14,050).

2-*Benzyl*-2-*deuterio*-3,3-*dimethyl*-1-*indanone* (**25**). A 0·25 g (0·001 mole) sample of **20** and 0·07 g MeONa in 2 ml MeOD were refluxed 12 hr. After evaporation of the solvent, the residue was extracted with 50 ml CCl_4 and treated with charcoal. Evaporation of the solvent gave 0·20 g of **25**, m.p. 64–65°. IR and UV spectra of **25** are nearly identical with those of **20**.

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[35] The PMR spectra were determined at 60 M c/s, using a Varian A-60 spectrometer, in dilute carbon tetrachloride or deuterochloroform solutions unless otherwise indicated with tetramethylsilane (δ = 0·00) as internal standard. All the compounds investigated were analytical samples prepared previously in this laboratory or as described below.